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MAGNETIC BREMMSTRAHLUNG IN A VARIABLE FIELD AS THE
MECHANISM BEHIND THE CHANGING RADIANCE OF
QUASISTELLAR RADIO SOURCES

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MAGNETIC BREMMSTRAHLUNG IN A VARIABLE FIELD AS THE MECHANISM BEHIND THE CHANGING RADIANCE OF QUASISTELLAR RADIO SOURCES*

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SUMMARY

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This paper draws particular attention to the variable radiance mechanism of quasistellar radiosources within the framework of the magnetic bremmstrahlung nature of their radiation. The author concludes that the radiance periodicity may constitute an indicator of the variations of radiosources' magnetic fields, due to inner processes in central regions. (Refer to [1 — 4]).

author

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The optical variability of 3C 273-B [5 - 6] and 3C 48 [4, 7] is at present reliably ascertained, and there are foundations to consider as variable the luminance of 3C 196 [7]. According to [6], it may be noted that the best studied source 3C 273 -B: a) has systematic oscillations of brillance with a period $P \approx 10$ years and b) discloses "flare-type" events of duration from a week to one month and with enhancement by a factor of two.

So far the nature of variable luminance of quasistellar radiosources is unknown and is hardly not the most mysterious peculiarity.

A series of hypotheses have been proposed in a rather general form [7-10] for the explanation of short-term fluctuations of luminance. The single attempt to explain periodical variations in the brillance of 3C 273 assumes [11] that the luminous equilibrium of the emitting region is subject to periodical disturbances on account of interaction with the surrounding medium.

It seems to be more natural to seek the explanation of the periodical variability first of all in the inner properties of the objects within the framework of the mechanism of their luminance. The optical emission of 3C 48 has a magnetic bremmstrahlung nature [4]; serious foundations are brought forth also relative to the continuous spectrum of 3C 273, which was originally ascribed to f — f transitions [12], in favor of magnetic bremmstrahlung nature [3]. In this connections it seems reasonable to view the periodical variations of quasistellar radiosource luminance as a result of oscillations of the basic parameters of the magnetic bremmstrahlung mechanism, that is the magnetic field intensity H and the concentration of relativistic electrons, N_e.

The contribution of these fluctuating terms to the observed luminosity variations may be, generally speaking, different. But, by the strength of the specific condition $T_0 \ll P$ [1), where T_0 is the characteristic time of optical losses, it seems natural to link long-period variations of shine with the oscillations of the magnetic field intensity in the first place, and not with the variation of the number of relativistic particles.*

The spectral density of the radiation provided by the aggregate of electrons in the magnetic field is

$$F_\nu \propto K_\nu H^{(\nu+1)/2} \nu^{-(\nu-1)/2},\tag{1}$$

where K_ν is a factor in the energy spectrum of relativistic electrons $N_e(E)dE = K_\nu E^{-\nu}dE$, related to the entire object of the source.

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* Obviously, the number of injected particles may be dependent upon the magnetic field. We only wish to underline here, that even in that case, the cause of luminous flux variations is in the variations of the magnetic field.

Assume, for instance, that the power of injectors is constant and independent from the magnetic field, that is, the electrons of invariable energy and concentration emit in a magnetic field of variable intensity (see below concerning the realization of this model). Then the relative variation of the flux is

$$\delta F_v / F_v = \tfrac{1}{2}(\gamma + 1)\delta H / H = (\alpha + 1)\delta H / H, \qquad (2a)$$

where $\alpha = (\gamma - 1)/2$ is the spectral index. The doubled amplitude of the oscillations of source's 3C 273 brillance constitutes $\approx 0.5 m$ [5], that is $\bar{\delta F}/\bar{F} \approx 0.26$. Assuming $\alpha = 0.2$ [3], we find $\delta H/H \approx 0.2$. Therefore, the 20 percent periodical variations of the magnetic field could have induced the observed periodical oscillations of luminance.

When admitting the proposed mechanism of light flux variations the brillance curves in various wavelengths must be phased, which is in agreement with the observations [7]. More important is the circumstance, that because of the nonpower-law character of the spectrum in the high-frequency region [4, 8, 12, 14] and frequency shift (at oscillations of the magnetic field), responding to synchronous emission spectrum maximum of a separate electron, a certain variation of chromatic indicators must take place along the brillance curve. The latter is noted indeed [4, 7].

The magnetic field variations in quasistellar radiosources may in principle be conditioned by causes of geometric and/or physical character.

I. Geometrical Nature of Magnetic Field Variability

The simplest geometry, realizing periodical field modulations is the rotation of the source, at which the visual ray is intersected by regions of variable intensity of the quasi-regular inhomogenous field. In this case the variation of object's luminance are described at constant injector power and without taking into account the nonsphericity of the nucleus by formula (2a) * The a priori basis of the expected rotation is the closeness of the frequency revolution of the particle moving in the

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* The low value of polarization of optical emission from 3C 273 [13] does not contradict the orderliness of the magnetic field, for the strong depolarization takes already place in the thin superficial layer of the optical source, where the regular field passes into a chaotic field of the nucleus (sustaining nucleus in quasistationary state). But if the rotation is not the direct cause of variability, the latter's mechanism may be linked with the very character of nucleus' sustaining by the magnetic field (periodical circulation of plasma: see part II).

gravitational field $M/\odot = 10^8$ at the distance $R = 2 \cdot 10^{16}$ cm (these values are generally utilized as parameters of the nucleus of 3C 273 [6,14,18], and frequencies of brillance variation in 3C 273. It is evident that the circular frequency of the experimental particle may also be considered as the upper value of the angular velocity of the optical source.

Note that the rotation of the core emitting a continuous spectrum, may not reflect in the atmosphere dynamically, where emission lines are formed. To the contrary, the assumption of the presence of shell rotation in coordination with the spectroscopically observed velocities leads to the law of rotation of the inner region and shell of the form $\omega \propto r^{-1}$, or to $V \approx$ const. The latter requires great masses $\sim 10^9 \div 10^{10} M_\odot$ at their low concentration toward the center, contradicting the comparatively small atmosphere mass [14,15]. Furthermore, the emission lines' profiles are not strictly rotational [3] and they point to the probable presence of nonstationary dynamic motions of the atmosphere.

Although the rotation of the nucleus (core) appears to be quite admissible, it is appropriate, on account of absence of its observational corroboration, to consider another possibility, promising more corrolaries compatible with observations.

II. - Physical Nature of Magnetic Field Variability

The region, from which the observed light flux emerges (such region can already be a comparatively thin emitting layer [1]), may be subject to the action of periodical disturbances, propagating from within, which modulate the magnetic field of the source. The pulsations of a massive star (supernova) may constitute the physical mechanism assuring the egress of such perturbations, when this star is situated inside the nucleus of the quasistellar source. Let us estimate approximately its parameters *. If the structure of the supernova, in whose quasistationary equilibrium the radiation plays the decisive role, is approximated by the polytrop of

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* Close estimates, based upon oriented values for the mass and dimensions of the object, were brought out earlier [2], where a comparison is also given with the empirical correlations for cepheides and long-period variables. The oscillatory model of 3C 273, considered in [20], is inconsistent, for it is based upon the erroneous expression for the frequency of radial oscillations.

the index $n = 3$, the natural frequency of its adiabatic radial pulsations [16] will be

$$\sigma_0 = 2\pi / P = [^9/_{10}(\Gamma - ^4/_3)\pi G\rho_c]^{1/2}. \qquad (3)$$

Here $\Gamma = \beta + (4 - 3\beta)^2(\gamma - 1) / [\beta + 12(\gamma - 1)(1 - \beta)]$ is the adiabatic indicator of plasma and radiation mixture; $\beta \equiv p_g / (p_g + p_r)$; ρ_c is the nonperturbed central density (for $n = 3$, $\rho_c = 54.1^\beta \rho^-$ [17]. In the case of interest to us, when $\beta \ll 1$ and $\gamma = ^5/_3$ (ideal plasma) $\Gamma = ^4/_3 + \beta/6 + \ldots$ If β and the molecular weight μ are constant by the "star", we may utilize for the required orderly estimates the precise result of the theory of polytrops $\mu\beta = 4.33 M_{/\odot}^{-1/2}$, where the coefficient responds to the polytrop $n = 3$ (see, for example, [19]), so that $\Gamma - ^4/_3 = 1.44 M_{/\odot}^{1/2}$. With supernova mass $M/\odot = 10^5$ to the observed value of oscillation period $P \approx 10$ years responds, according to [3], $\rho_c \approx 5 \cdot 10^{-7}$ g/cm^3; at the same time $R \approx 2 \cdot 10^{15}$ cm and $T_c \approx \approx 10^{6}$ °K (the relativistic correction for the frequency of pulsations is here neglectingly small), For these conditions the nuclear energy yield is still insufficient, and the supernova illuminates only at the expense of the compression work, provided only it is not endowed with matter concentration toward the center greater than at a polytrop with $n = 3$ (models with higher concentration correspond better to standard variable stars).

Although the supernova may constitute only a small fraction ($\sim 10^{-3}$) of the dynamic mass of the quasistellar radiosource's nucleus, its magnetic field is the essential part of the field in which radiation of optical electrons takes place. In the magnetosphere such a field (tens of oe per $R \gg 10^{16}$ cm for 3C 273 [1]) gives $H \approx 10^4$ oe for the dipole term of the relict field having formed at compression in the course of magnetic collapse of a large mass from a state, for example, with $\rho_0 \approx 10^{-26}$ g/cm^3, $H_0 \approx 10^{-7}$ oe. The presence of a large field in the supernova strongly counteracts the convection, materializing the energy transfer. It may be shown that inasmuch as the radial temperature conductivity exceeds a great deal the magnetic and radial viscosities, the convection takes place in the form of oscillating instability, leading to wave propagation with rising amplitude [22] and contributing to the upkeep of supernova pulsations.

If during the variations of magnetic field intensity, induced by the pulsations of supernova surface, the density of relativistic electrons

of the given energy remains, as an average, invariable, then $K_r \propto r^3$, and, taking into account the preservation of the magnetic flux at pulsations from [1] we have

$$\delta F_\nu / F_\nu = \frac{1}{2}(\gamma - 2)\delta H / H. \qquad (2b)$$

In this case, at $\gamma \approx 2$, the luminance oscillations at field variations must be absent owing to the compensating variation of the number of relativistic particles in the radiating region. But if the conditions of injection themselves depend on the field, and, say, the energy of incoming particles varies adiabatically with the change in the dimension of the region, we have $K_r \propto r^{-(\gamma-1)}$ and

$$\delta F_\nu / F_\nu = \gamma \, \delta H / H. \qquad (2c)$$

Evidently, in the last case, intermediate between (2a) and (2b), $\delta H / H \approx 0.2$, is required for the periodic oscillations of the brillance of 3C 273, so that the required change in the dimensions of the emitting region is $\delta r / r \approx 0.1$. For comparison let us note, that at oscillations of cepheids $\delta r / r \approx 0.05 \div 0.1$.

Apparently, the fluctuations of the magnetic field take place on the dynamic background, being attended by secular compression of the nucleus (because of energy dissipation), as well as of the supernova (so long as the nuclear yield in it is insufficient), and, possibly, by a certain widening of the emitting layer when the light flux from the nucleus increases. The freeze-in condition of the magnetic field into the plasma will lead to a systematic decrease of field intensity, and, consequently to a decrease in radiance. It is easy to show that the model (2c) provides a drop of the light flux by 0.4^m already at widening of the emitting layer in 3C 273 with $V = 10^6$ cm/sec (per century). It is interesting that an identical secular weakening of radiance is rather reliably noticed from the observation material encompassing some 80 years [6, 23]. If the supernova still is in the state of secular compression within the quasistellar radiosource, the period of its pulsations will vary by $\propto \rho_c^{-\frac{1}{2}}$ in correspondence with [3].

The field modulations may also take place as a result of circulatory motions in the nucleus [24]. Because of the impossibility of pure periodicity of the latter, turbulence is unavoidable, leading to flare-type events.

Alongside with the fluctuations of the magnetic field induced by it, ejections of relativistic particles may contribute to sporadic brillance variations of the quasistellar radiosource. The choice between the possible combinations of δH and δN_e in this case, as in the above-considered one of periodical field oscillations may be made by way of analysis of chromatic indicators; the parallel measurements of γ-ray fluxes from 3C 273 have their importance, inasmuch as their variations will be quantitatively differing, depending upon, whether or not, the concentration of relativistic electrons varies alongside with the the density of thermal photons. It is not excluded, that in certain quasistellar radiosources, observed during the stage of strong matter concentration toward the center, the radioluminance may also found to be variable.

Summing up the above-said, it is possible to conclude that the radiance oscillations of quasistellar radiosources constitute an effective indicator of variations of their magnetic field, due to inner processes in central regions.

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